The Geological Survey of Wyoming
Daniel N. Miller, Jr., State Geologist

UPDATE ON THE WYOMING-IDAHO-UTAH THRUST BELT: JOINT MEETING OF THE WYOMING GEOLOGICAL ASSOCIATION, WYOMING GEOLOGICAL SURVEY, AND DEPARTMENT OF GEOLOGY AT THE UNIVERSITY OF WYOMING

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Compiled by
David R. Lageson

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Cover photo. Crest of the Salt River Range, looking south from the summit of Prater Mtn. (elev. 10,078 ft.). The rugged topography is carved in a terrane of Paleozoic strata (mostly limestone) in the hanging wall of the Absaroka thrust fault.

UPDATE ON THE WYOMING-IDAHO-UTAH THRUST BELT

Drilling in the overthrust......

Photo: #24-14 Middle Ridge Unit
True Oil Company
se sw sec. 14, T.35 N., R.117 W.
Lincoln Co., Wyoming
(Summer, 1978)

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April, 1979
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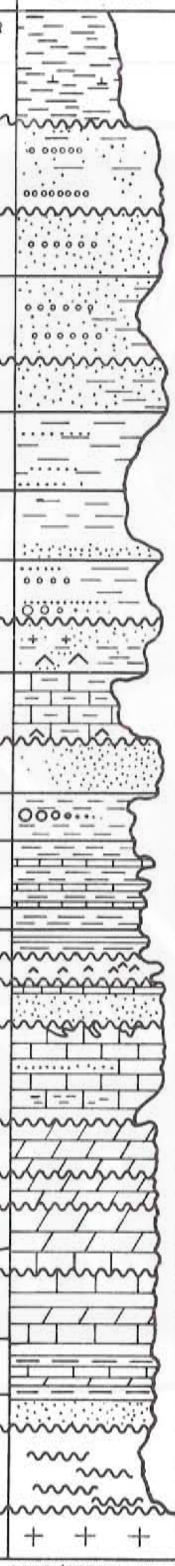
TABLE OF FORMATIONS

WYOMING-IDAHO-UTAH FOLD AND THRUST BELT

(BEAR RIVER RANGE - MOXA ARCH)

AGE		FORMATION OF GROUP		THICKNESS	FACIES
TERTIARY		SALT LAKE GRP.	GREEN RIVER GRP.	0-8000'	LAKE BEDS
		WASATCH GRP.			CONTINENTAL
CRETACEOUS	UPPER	ADAVILLE FM.		6000 - 16 000'	CONTINENTAL / DELTAIC / MARINE
		HILLIARD FM.			
		? FRONTIER FM.			DELTAIC / MARINE
	LOWER	ASPEN FM.		1000-10,000'	DELTAIC / MARINE
		BEAR RIVER GRP			DELTAIC / MARINE / DEL-TAIC
		GANNETT GRP			CONTINENTAL / DELTAIC
JURASSIC		? ? STUMP - PREUSS FMS.		500 - 1000'	MARINE (LOCALLY RESTRICTED)
		TWIN CREEK FM.		1500 - 3500'	MARINE
		NUGGET		0-2000'	CONTINENTAL
TRIASSIC		ANKAREH		2000-7000'	CONTINENTAL
		THAYNES			MARINE
		WOODSIDE			
		DINWOODY			
PERMIAN		PHOSPHORIA		400-5000'	MARINE
PENNSYLVANIAN		WELLS	TENSLEEP AMSDEN	750-4000'	MARINE
MISSISSIPPIAN		BRAZER	MADISON	1000 - 7000'	MARINE (LOCALLY RESTRICTED)
		LODGEPOLE			MARINE
DEVONIAN		THREE FORKS	DARBY	500 - 3000'	MARINE
		JEFFERSON			
SILURIAN		LAKETOWN		0 - 2000'	MARINE
ORDOVICIAN		FISH HAVEN	BIGHORN	250 - 2000'	MARINE
		SWAN PEAK			
		GARDEN CITY			
CAMBRIAN		ST CHARLES	GALLATIN	1500 - 5000'	MARINE
		WORM CREEK			
		NOONAN			
		BLOOMINGTON	GROS VENTRE		
		BLACK SMITH			
		UTE			
		LANGSTON			
		BRIGHAM	FLATHEAD		
PRECAMBRIAN		SEDIMENTS & METASEDIMENTS			
PRECAMBRIAN		CRYSTALLINE BASEMENT			

LITHOLOGY



NOTE QUATERNARY-0-4000' OF SAND/GRAVEL-OFTEN BEDDED-6000-8000 FEET/SECOND

SOURCE: PETROLEUM INFORMATION, 1978
"THE OVERTHRUST BELT"

INTRODUCTION

by
David R. Lageson
Geological Survey of Wyoming

This Thrust Belt Conference has been organized for the annual joint meeting of the Wyoming Geological Association, Geological Survey of Wyoming, and the Department of Geology at the University of Wyoming, scheduled for April 27th and 28th, 1979, in Laramie.

The eastern Cordilleran fold and thrust belt is a major tectonic province extending over 3,000 miles in length through western North America. It is a region of complex structural geology, rapid facies changes and a complicated tectonic history. Many geological factors have contributed to make the fold and thrust belt economically attractive to petroleum and mining explorationists. Giant oil and gas fields in the Alberta segment of the fold and thrust belt, as well as tremendous phosphate reserves in Idaho, demonstrate the economic potential. The discovery of Pineview field, Summit County, Utah, in 1975, has recently focused the oil industry's attention to the Wyoming-Idaho-Utah salient. This conference serves as an update of mapping, exploration, and development activities in the Wyoming-Idaho-Utah salient, as well as areas north of the Snake River Plain in eastern and central Idaho and western Montana.

Abstracts in this publication have been submitted by conference speakers. In addition, there are a few non-speaker abstracts of general interest. It is hoped that this publication will not only serve as a program for the meeting, but will also serve as a reference source for recent activities in the thrust belt by industry, the universities, and survey personnel.

I wish to thank Mr. Jim Goolsby (Casper, Wyoming) for his help in coordinating this meeting with the Wyoming Geological Association. I also thank the speakers and exhibitors for their willingness to participate in this conference. The staff of the Geological Survey of Wyoming have provided much help, for which I am grateful.

GEOMETRY OF THE PROSPECT-DARBY AND LA BARGE FAULTS AT THE JUNCTION WITH THE LA BARGE PLATFORM, LINCOLN AND SUBLETTE COUNTIES, WYOMING

D. L. Blackstone, Jr., University of Wyoming, Laramie, Wyoming

The eastern margin of the Wyoming salient of the foreland fold and thrust belt of western Wyoming lies approximately 15 miles west of Big Piney, Wyoming, and approximately six miles west of La Barge, Wyoming. Three major, low angle, west dipping reverse faults have been described in the area--the Darby, the Prospect and the Hogsback. The Hogsback fault plate on the basis of attitude, internal stratigraphy and structure is the actual continuation of the Darby thrust plate, offset to the east by strike slip movement on the Thompson fault. The latter is a tear fault in the Darby plate with left lateral movement of about three miles. The name Hogsback thrust should be abandoned. The major faults are considered to bottom out on a decollement in the Cambrian strata lying above the west dipping surface of the Precambrian basement.

The Moxa arch of western Green River basin merges to the north into the broad anticline of the La Barge platform. The platform trends approximately N 45^{o} W, passes beneath the thrusts of the salient and may continue as far northwest as the Star Valley graben. The platform is older than the thrusting and appears to have deflected the trend of the major low angle thrust faults.

The Upper Cretaceous stratigraphic section lying above the Aspen Shale and below the Adaville Formation exposed in Snider Basin (T.29 N., R.115 W.) has been reported to be over 12,500 feet in thickness. Such a thickness is completely anomalous to the same section as encountered in wells drilled immediately east of the thrust belt in the Big Piney producing district. The reason for the anomalous section is repetition by reverse faulting. The Frontier-Hilliard section is repeated by three reverse faults which surface in Snider Basin. The faults trend north to northwest, dip to the west and are upthrown on the west side. When the section is corrected for repetition by faulting it agrees very well in both thickness and lithological character with the drilled sections to the east.

Review of subsurface data in the area of the Tip Top, Dry Piney and South Hogsback producing areas reveals two west dipping reverse faults below the Darby thrust plate which repeat the Cretaceous section. The faults are the Tip Top fault to the north and the more extensive La Barge fault to the south. The maximum slip is on the La Barge fault--15,000 feet. The Tip Top can be traced downward to the west to the level of the Nugget Sandstone, and probably continues downward to the major decollement in the Cambrian strata.

East dipping thrust faults are also present. At the Tip Top field an east dipping fault--the Cretaceous Mountain thrust--is of limited extent. In the La Barge area and extending farther to the south is the Calpet fault. Previous structural sections have not adequately considered these faults. No root zone or primary decollement has been established for the east dipping faults.

THRUSTBELT STRUCTURAL STYLES OF THE CHARLESTON-STRAWBERRY PLATE NEAR HEBER CITY, NORTHEAST UTAH

Dan Davis, Gulf Exploration and Production

There are five or six major north-south trending thrust systems in southwest Wyoming and southeast Idaho, north of the east-west axis of the Uinta Range. However, south of this axis and east of the Wasatch Front, only one major thrust system, the Charleston-Strawberry, is exposed at the surface. The Charleston-Strawberry thrust has also been called the Charleston-Nebo and Leamington thrust.

The Charleston-Strawberry plate consists of moderately deformed allochthonous Pre-Cambrian, Paleozoic, and Mesozoic rocks which have been displaced eastward a minimum of 25 to 30 miles by Sevier orogenic forces. Similar and chevron folds are exposed in Provo Canyon, and well data indicate overturned and imbricated folds in the Diamond Fork anticline and the Mountain Fuel #1 Thistle Dome unit.

The leading edge of the Charleston-Strawberry thrust places Oquirrh rocks on Twin Creek strata near Lake Creek Road, and overturned Twin Creek and Park City strata on Upper Cretaceous Mesa Verde strata in the Co-op Creek area. Jurassic rocks in the Lake Creek Road area dip southwest and presumably are present below the Charleston-Strawberry plate in the Daniel's Canyon area. In the Daniel's Canyon area, only Virgilian and Missourian rocks of the Charleston-Strawberry plate are exposed and may not exceed 7,500 feet in thickness. Seismic interpretation of several lines in the Daniel's Canyon area indicates that the Charleston-Strawberry detachment (?) lies 8,500 to 11,000 feet below the surface.

A second major thrust detachment lies below the interpreted seismic trace of the Charleston-Strawberry thrust plane and is referred to as the Co-op Creek thrust by this author. This plate is believed to be composed of moderately deformed Cretaceous, Jurassic, Triassic, and Upper Paleozoic (?) strata. Horizontal and vertical displacements on this thrust plate are probably of small magnitude.

Normal faulting resulting from extensional tectonics of Eocene and younger ages have severely deformed original thrust planes produced during the Sevier Orogeny. The Wasatch fault in the Utah Valley graben, for example, has displaced Paleozoic rocks at least 14,000 feet as evidenced by Tertiary strata in the Gulf #1 Banks well in Spanish Fork, Utah.

Thrusting chronology and correlation of the Charleston-Strawberry thrust with the major thrusts in southwest Wyoming is difficult. Relative age of thrust activity is suggested by three syntectonic clastic deposits: the Indianola (Aptian-Albian), Price River (Maestrichtian (?)) and North Horn (Danian to Montian of the Paleocene).

NATURAL GAS POTENTIAL, THRUST BELT AND GREEN RIVER BASIN

M. J. Doelger, J. A. Barlow, Jr., L. A. McPeek, J. D. Haun,
Barlow & Haun, Inc., Casper, Wyoming

A significant natural gas supply is available in the central Rocky Mountain region from the Green River, Wind River and Uinta-Piceance basins, and the Thrust Belt. The central Rocky Mountain region has produced 7 TCF and has reserves of 14 TCF. Five TCF reserves have been added in the past three years. Potential resources are in the 73-to-89 TCF range; the heavily-drilled greater Green River Basin and the newly-developing Thrust Belt account for 60% of this resource estimate.

The Thrust Belt and greater Green River Basin are structurally separate, but can be considered to be one gas province. Cretaceous source rocks in both areas were subjected to temperatures, pressures, and timing of events optimum for generation of natural gas. Current production reflects the gassiness of the province; in 1978 more than half of Wyoming's total production of 330 BCF was from the greater Green River Basin and the Thrust Belt.

In an extensive study completed in April 1977 we estimated that the greater Green River Basin had a potential gas resource of 23 TCF and an estimated reserve of 5 TCF. Since April 1977 two-hundred and nine gas wells have been completed and the reserves have increased by 26%. These encouraging results and the current level of drilling activity add credibility to the 23 TCF resource estimate. Most of this gas is in Upper Cretaceous reservoirs. The pre-Cretaceous rocks of the basin's large anticlines account for only 1.3-to-3.9 TCF resources.

The Thrust Belt potential gas resource matches or exceeds the greater Green River Basin gas resource. Most of the gas which is in Paleozoic and Jurassic formations in anticlines in the hanging wall of thrust sheets was generated from Cretaceous rocks of the foot wall, then migrated along faults and fractures to accumulate in the structural closures. Reserves are 45-to-90 BCF per section estimated from currently productive anticlines. One or two potentially productive structural closures per township are present throughout the Thrust Belt with 2-to-6 sections within each structural closure. Timing of geologic events, reservoir rock characteristics and the relationship of source to reservoir rock are the most sensitive factors effecting potential productivity. Many structures will be non-productive. The Thrust Belt can be divided into an area of primary and an area of secondary potential. Thirteen fields have been discovered in the area of primary potential which covers about 90 townships and includes the Absaroka and Hoback-Darby thrust plates. The area of secondary potential covers about 160 townships and includes the western Crawford thrust plate and the northern Thrust Belt north of the Big Piney-La Barge area. We have assigned a probability for production of 80% to closures in the primary potential area and 30% to closures in the secondary potential area. The undiscovered resource estimate for the Thrust Belt (Wyoming, Utah and Idaho segment) is thus estimated to be in the 16.5-to-33 TCF range.

At the present rate of production the 8-to-10 TCF established reserves of the greater Green River Basin and Thrust Belt will last about 50 years; the 40-to-56 TCF potential resource could support a six-fold increase in production to 1 TCF/year for an additional 40-to-60 years.

FOSSIL MAMMALS, STRATIGRAPHY AND STRUCTURE, EARLY CENOZOIC, LABARGE, WYOMING

John A. Dorr, Jr., Department of Geology and Mineralogy, The University of Michigan, Ann Arbor, Michigan, and Philip D. Gingerich, Museum of Paleontology, The University of Michigan, Ann Arbor, Michigan

Recent additional collections of fossil mammals from the early Cenozoic Chappo Member of the Wasatch Formation, stratigraphic studies and geologic mapping in the vicinity of Hogsback Ridge west of LaBarge, Wyoming permit refinements in dating of the Chappo Member, a better understanding of the geographic and temporal relationships and origin of continental red beds on a regional scale, and closer temporal control on the time of movement on the Hogsback Thrust in that area relative to movements on other thrusts in the region.

Three fossil mammal localities now have been found in the Chappo Member. A collection from the type locality, on the South Fork of Chappo Gulch just east of Hogsback Ridge, which we have expanded and restudied, is middle Tiffanian (middle late Paleocene) in age. An expanded and restudied collection from the same member of Buckman Hollow, on the western flank of Hogsback Ridge, is Clarkforkian (earliest Eocene) in age. A small, new mammal faunule from the Chappo Member, about one mile south of Calpet, is late Graybull equivalent or Lysite equivalent in age. Thus, deposition of the Chappo Member began at least as early as middle late Paleocene and continued until at least as late as middle early Eocene. The Chappo cannot be younger than Lysite in age because it is overlain with angular unconformity by the LaBarge Member of the Wasatch Formation, from which fossil mammals of Lost Cabin equivalent age have been collected.

Good mammalian geochronologic and stratigraphic control now is available for a number of relatively continuous, late Cretaceous and early Cenozoic stratigraphic sequences at several places in the Green River and Hoback basins of western Wyoming, the Fossil Basin of southwestern Wyoming, the Big Horn Basin of northcentral Wyoming and the Echo Canyon area of northeastern Utah. Comparisons of these data with respect to time, place and level of appearance of red conglomerates and variegated red beds as opposed to drab colored sequences indicate the following: (1) red conglomerates and color variegated red beds first appear at different times and in different places from one site to another, both within single structural-depositional basins and from one basin to another; (2) red beds, in the course of time, appear, disappear and then reappear again at some localities; (3) red beds at certain localities were deposited synchronously with and grade into drab beds over short distances; (4) red beds appear earlier in the western than in the eastern part of the Overthrust Belt; (5) coarse grained, red clastic deposits are synorogenic and exhibit a close temporal and geographic relationship to tectonic events and features, such as overthrusting and related uplift; (6) red colors did not develop in otherwise appropriate sites of fluviatile clastic deposition if the sedimentary source areas did not provide oxidized or oxidizable iron in sufficient quantity. It is clear that the first appearance of red beds does not, contrary to what some workers believed, mark the Paleocene-Eocene boundary. We propose that a model presented by Braunagel and Stanley (Jour. Sed. Petrol., v. 47, no. 3, 1977, p. 1201-1219) can be expanded upon in time and space to explain our observations. We suggest that: (1) synorogenic, fluviatile clastic deposits may or may not have developed red coloration, depending upon the availability of sufficient oxidized or oxidizable iron from a source area; (2) uplifted source areas were created by tectonic events, in this region specifically the major overthrusts of the late Cretaceous and early Cenozoic; (3) the time of uplift of source areas tended to be younger eastward in direct relationship with the younger eastward progression of major overthrusts; (4) rates of clastic deposition were most rapid closest to their source areas and relatively slower toward the centers of depositional basins; (5) the result of 4 was the creation of depositional surfaces which were altitudinally high on coarse talus (diamictite) deposits on the flanks of uplifts and sloped downward through generally fining alluvial fan, alluvial apron and alluvial plain depositional environments, in some cases eventually reaching deltaic or even lacustrine (e.g. Green River Lakes) environments toward basin centers; (6) the regional water table tended to stand well below the depositional surface for substantial lengths of time in the higher, basin flank deposits, but approached and eventually reached the depositional surface toward the basin center, thus leading to a progressive change, geographically, from the oxidizing environment of red bed formation proximal to uplifts to reducing environments of drab sequence formation distally; (7) depositional rates and environments changed through time, as uplifted sources areas were eroded down, when tectonic events created new uplifts or renewed older ones in the same or different places, or as basin subsidence rates changed, thus leading to variations in time and space for the appearance of red beds; (8) red colors are generated in sediments under a rather wide range of climatic conditions; thus, an adequate climate would have been a necessary factor, but the other conditions listed would also have been required if we are to have a sufficient explanation, and the appearance of red beds would neither have been time synchronous everywhere nor mark a climatic change boundary in space or time.

The following conclusions regarding the structural history of this area, and adjacent parts of the same region, are suggested by our work: (1) The Hogsback Thrust overrides the late Cretaceous ?Adaville Formation but is overlapped by the Chappo Member of the Wasatch Formation. Therefore, the Hogsback Thrust is post-Campanian but pre-middle Tiffanian. If the Hogsback Thrust is a southward extension, displaced eastward, of the Darby Thrust, then this gives an approximate date for Darby Thrust movement, but does not rule out the possibility that the Darby (?=Hogsback) Thrust could be as old as or older than the Absaroka Thrust, although this may seem unlikely in view of the general tendency of major thrusts to be younger eastward. (2) The Prospect Thrust has been closely dated farther north, in the Hoback Basin area, where it is post-Tiffanian and pre-Graybull equivalent in age; thus, regardless of what the geometric relationships are between the Hogsback, Darby and

Prospect thrusts, their times of movement are different between the northern and central parts of the Overthrust Belt. The proposal of Royse *et al.* (1975) that the Prospect Thrust ramped up into the Darby (?=Hogsback) Thrust and caused a second episode of movement along the southern part of the Darby Thrust is difficult to reconcile with our data which show that the last movement on the Hogsback Thrust occurred before movement along the Prospect Thrust. (3) The LaBarge Thrust cut the Hogsback Thrust and also deformed the Chappo Member, but was overlapped by the LaBarge Member of the Wasatch Formation. This makes the time of movement on the LaBarge Thrust later than movements on both the Hogsback (?=Darby) and Prospect thrusts. (4) These age relationships suggest that if any two or all of the Hogsback, Darby, Prospect and LaBarge thrusts are geometrically linked, then the times of movement on at least some of these must have been different from north to south. Alternatively, they may not have been linked. Our data do not resolve these problems.

THE ANTLER OROGENIC BELT IN CENTRAL IDAHO--EVIDENCE FROM THE PIONEER MOUNTAINS

James H. Dover, U.S. Geological Survey, Denver, Colorado

Structural telescoping of argillaceous (western-facies) lower Paleozoic sequences with time-equivalent calcareous and quartzitic (eastern-facies) rocks in central Idaho resembles that along the Roberts Mountains thrust system of Nevada. This similarity has led numerous authors to project the Antler orogenic belt north from Nevada through the zone of facies juxtaposition in the Pioneer Mountains. However, structures equivalent to those of the Roberts Mountains thrust system have not been demonstrated in the Pioneer Mountains, where palinspastic reconstruction of the Antler orogenic belt is complicated by the effects of major post-Antler thrusting.

Stacked allochthons in the Pioneer Mountains include not only the western-facies lower Paleozoic sequences, but also thrust sheets of Precambrian quartzo-feldspathic gneisses and lower Paleozoic high-grade metasedimentary rocks, Mississippian flysch of the Copper Basin Formation and Pennsylvanian-Permian Wood River Formation. These allochthons override unmetamorphosed lower Paleozoic carbonate rocks exposed in structural windows. Major movement on dated thrust faults occurred mainly in the Mesozoic, between the time of deposition of the middle Permian part of the Wood River Formation and emplacement of 78-m.y.-old rocks of the Idaho batholith. Some thrusts predate or were synchronous with a regional metamorphic event associated with generation of the Idaho batholith, and other thrusts postdate the metamorphism. The difference in structural style between tightly folded, imbricated, and commonly sheared argillites of the western-facies lower Paleozoic and broadly folded calcareous sandstone of the overlying Wood River allochthon raises the possibility that the western-facies rocks were affected by pre-Pennsylvanian deformation not experienced by the Wood River; if so, that deformation could have been related to the Antler orogeny. However, other allochthons that underwent only Mesozoic movement have structural styles and complexity comparable to those of the western-facies sequences. Therefore the alternative can not be eliminated that all observed style differences among allochthons resulted from disharmonic response to entirely Mesozoic regional thrusting in rock sequences of different competence or at different structural levels.

The only uneqivocal evidence for the Antler orogeny in central Idaho is still the Copper Basin Formation, a flysch deposit that required a western highland source of argillite, chert, and quartzite in Mississippian time (Poole, 1974; Paull, 1976). The main constraint in establishing the position of the Antler highland (and, by inference, the orogenic belt) is in restoring the site of flysch deposition. The flysch now occurs in two superimposed allochthons. The structurally lower allochthon contains broadly folded rocks of a marine limestone-bearing facies estimated to have moved a minimum of 15-20 km eastward; the upper allochthon contains tightly folded and cleaved rocks of a carbonate-poor, mainly terrigenous facies that originally was deposited west of the marine facies and that was internally shortened at least 50 percent by folding during translation. Palinspastic reconstruction requires that the original Antler flysch basin extended a minimum of 50-75 km west of the Pioneer Mountains and, consequently, that the Antler orogenic belt probably reached no farther east in Mississippian time than the southwesternmost part of the present Idaho batholith.

Western-facies lower Paleozoic strata were deposited on the outer slope of a depositional wedge that extended into eastern Oregon, well beyond the present western limit of Precambrian basement indicated by Sr-isotope data (Armstrong and others, 1977). I conclude that thrusting of the western facies into the Pioneer Mountains occurred in at least two major stages: (1) overriding of the outer shelf by rocks of the argillaceous slope facies in Mississippian time, forming the Antler highland from which flysch was shed eastward into a marine trough; and (2) subsequent eastward thrusting, in two or more pulses of Mesozoic age but possibly beginning as early as Late Permian. This second stage involved tectonic slices of metamorphosed shelf rocks and underlying Precambrian basement, eastward movement and imbrication of the flysch sequence, and rethrusting of the western-facies rocks of the Antler belt over the tectonic remnants of the flysch. Estimated total translation of 200 km, divided about equally between the two major stages, is a minimum, to which it may be necessary to add the increment of eastward movement represented by the thrust systems of eastern Idaho and western Montana.

References cited

Armstrong, R.L., Taubeneck, W.H., and Hales, P.O., 1977, Rb-Sr and K-Ar geochronometry of Mesozoic granitic rocks and their Sr isotopic composition, Oregon, Washington, and Idaho: Geological Society of America Bulletin, v. 88, no. 2, p. 397-411.

Paull, R.A., 1976, Evidence against Antler-age thrusts in south-central Idaho: Geological Society of America Abstracts with Programs, v. 8, no. 5, (Albuquerque), p. 617-618.

Poole, F.G., 1974, Flysch deposits of the Antler foreland basin, western United States, in Dickinson, W.R. (ed.), Tectonics and sedimentation: Society of Economic Paleontologists and Mineralogists, Special Publication no. 22, p. 58-82.

STRUCTURAL GEOLOGY OF THE NORTHERN SALT RIVER RANGE, IDAHO-WYOMING THRUST BELT--A PRELIMINARY REPORT

David R. Lageson, Geological Survey of Wyoming, Laramie, Wyoming

The northern Salt River Range is the structural culmination of the Absaroka - St. Johns thrust complex. The Stewart Peak quadrangle, located on the culmination, has been mapped to gain an understanding of the nature of the thrusts and folds in this part of the Idaho-Wyoming thrust belt. Rocks ranging in age from Middle Cambrian through Upper Cretaceous are interleaved in a complex array of imbricate thrust faults and asymmetric folds.

Major thrust faults in the Stewart Peak quadrangle include the Absaroka, Murphy, and Firetrail. Imbricate thrusts in the hanging wall of the Absaroka include the Star, Stewart, and four imbricate slices at the north-central margin of the quadrangle which may correlate with the St. Johns complex in the Snake River Range. The Grand Valley fault bounds the range near the west margin of the quadrangle where fanglomerates of probable Tertiary age (Pliocene?) are offset against Middle and Upper Cambrian strata.

Several conclusions may be proposed regarding the northern Salt River Range. First, cataclasis occurs on a scale much greater than previously reported because deeper and more intensely deformed levels of the thrust belt are exposed relative to thrusts cropping out to the east and south in the Idaho-Wyoming salient. Second, deformational intensity increases downward through the Paleozoic succession as the basal Absaroka decollement in the Cambrian Wolsey Shale is approached. Third, stratigraphic thicknesses for units below the Mississippian Madison Group are tectonically thickened by ubiquitous small-scale thrust slivers (each with a few centimeters or more offset), stylolites, and small-scale folds. Stratigraphic correlations and isopach studies based on the present distribution of tectonically thickened Paleozoic units should not be made in this part of the thrust belt. Fourth, the Stewart Peak area represents a structural culmination in which the roots of the Absaroka thrust have been exposed, possibly due to thrusting over a basement arch. In this regard, isopach trends of Cretaceous rocks east of the Darby-Hogsback thrust suggest the Moxa arch may continue to the northwest beneath the thrust belt in alignment with the Stewart Peak culmination. In addition, several structural discontinuities within the thrust belt northwest of LaBarge suggest the influence of a basement upwarp (D.L. Blackstone, Jr., in press). The Stewart Peak culmination may therefore reflect a deeper structural level of exposure due to thrusting over a basement arch above the regional level of decollement. This interpretation has important ramifications regarding the structural control of potential oil and gas reservoirs beneath the Absaroka thrust.

NEW, HIGH-RESOLUTION LANDSAT IMAGERY

Ronald W. Marrs, Remote Sensing Laboratory, Department of Geology, University of Wyoming, Laramie, Wyoming

A high-resolution Return-Beam Vidicon (RBV) system was put into operation March 5, 1978 with LANDSAT-III. The system uses two vidicon cameras mounted side-by-side and operating alternately to produce imagery with approximately twice the spatial resolution of previous LANDSAT systems. The instantaneous field-of-view of the new system is 38 meters square, compared to the 79-meter field-of-view of the old LANDSAT systems. The new RBV operates in a broad band of the visible spectrum (505 nm - 750 nm), so the images are spectrally equivalent to a normal black-and-white photo with the blue spectral component filtered out. The imaging geometry and higher resolution of the new system require that the data be presented as four subscenes (1:500,000 scale) covering an area the same size as the LANDSAT MSS scene. Each RBV subscene covers an area 98 km square.

LANDSAT-III also carries a multispectral scanner (MSS) which provides 4-channel multispectral data similar to that provided by previous LANDSAT systems. Each MSS image covers an area 180 km by 183 km.

STRATIGRAPHY AND SOME PETROLEUM ASPECTS OF THE AMSDEN FORMATION AND ASSOCIATED ROCKS IN THE THRUST BELT, WESTERN WYOMING

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The Amsden Formation includes a sedimentary sequence deposited during eastward transgression of the Early Pennsylvanian sea from the Cordilleran geosyncline onto the Wyoming shelf. The Horseshoe Shale and Ranchester Limestone Members of the Amsden in western Wyoming lie between a prior transgressive sequence of Late Mississippian (Chesterian) age and a subsequently deposited sequence of Middle to Late Pennsylvanian age. The underlying sequence is equivalent to the Big Snowy Group in Montana and includes the Darwin Sandstone Member of the Amsden; the overlying sequence is part of the Wells Formation. Epeirogenic uplift of the Wyoming shelf near the end of the Mississippian Period led to erosion of the Chesterian rocks from the shelf except for broad patches of the basal Darwin. Subsequent uplift in the vicinity of the outer shelf adjacent to the geosynclinal trough formed the Bannock highland in western Wyoming and eastern Idaho. The local arching of the Bannock highland may have developed as part of the Late Mississippian or Early Pennsylvanian epeirogeny that occurred prior to the Early Pennsylvanian transgression. If this is the case, the Horseshoe and Ranchester overlap the flanks of the highland. However, the presence of isolated and probably beveled remnants of red beds like the Horseshoe that rest upon Upper Mississippian rocks on the highland suggest that uplift did not take place until after deposition of the lower Pennsylvanian sequence. The upper Pennsylvanian sequence, part of the Wells Formation, covers the Bannock highland and lies unconformably upon rocks of the lower Pennsylvanian sequence and older, Mississippian strata.

Mudstone and interbedded limestone of the Upper Mississippian (Big Snowy) sequence that are rich in organic matter are probable petroleum source rocks. They overlie the Darwin in western Wyoming and adjacent areas. Like the Darwin, these source rocks occur as patchy remnants in parts of western Wyoming, because they had been extensively eroded or completely stripped from large areas prior to the Early Pennsylvanian transgression. Strata equivalent to these source rocks are widely preserved in the westerly thrust plates, but their dominant lithology is limestone, probably less productive as a source rock.

Sandstone of the Darwin seems to have been deposited in several shore environments that probably included offshore bar, beach, and eolian dunes. High porosity and permeability and sealing by impervious mudstone strata of the unconformably overlying Horseshoe indicate that the Darwin may contain hydrocarbon reservoirs. High temperature, owing to deep burial of the upper Paleozoic rocks in much of the thrust belt, may have destroyed these hydrocarbons; but there are indications that the temperature may not have been excessive in some parts of the region.

APPLICATIONS OF PALYNOLOGY TO STRATIGRAPHIC AND STRUCTURAL INTERPRETATIONS IN THE THRUST BELT OF WYOMING AND UTAH

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Studies of the stratigraphic distribution of fossil pollen, spores, and dinoflagellates are facilitating age determinations, correlations, and paleoenvironmental analyses of both marine and nonmarine rocks in the central Rocky Mountains. Palynology is contributing especially to interpretation of structural relations and reconstruction of tectonic history within the thrust belt of Wyoming and Utah.

At Snider Basin, Wyoming, a thick sequence of marine and nonmarine Cretaceous rocks is present but poorly exposed at the surface. Palynological analysis of surface samples collected through more than 10,000 feet of section indicates a normal succession of the Bear River Formation and Aspen Shale, and of equivalents of the Frontier Formation and Hilliard Shale in the lower 4500± feet of section. In the upper 6000+ feet of section, a recurrence of some of the palynomorph zones indicates that the same upper Frontier-lower Hilliard sequence is repeated within what has been mapped as a normal succession of the Blind Bull Formation. The presence of a thrust fault or tight synclinal fold is suggested by the palynological evidence, although surface expressions of such structures are not apparent.

Palynology has proved to be useful in dating syntectonic deposits related to episodes of thrust faulting. The Echo Canyon Conglomerate of northeastern Utah is believed to have been derived from the uplifted Crawford thrust plate; palynomorphs indicate the Echo Canyon to be equivalent to part of the Hilliard Shale of southwestern Wyoming, and they suggest that movement of the Crawford thrust occurred in Coniacian time. A syntectonic conglomerate in the Little Muddy Creek area of Wyoming, interpreted as related to the Absaroka thrust fault system, appears to record an early episode of movement of the Absaroka thrust; palynomorphs show that the conglomerate is probably equivalent to the uppermost Hilliard Shale (Santonian?). Later movement of the Absaroka fault system is dated as Campanian-Maestrichtian by the occurrence of palynomorphs in the syntectonic Hams Fork Conglomerate Member of the Evanston Formation.

In northeastern Utah a conglomerate-bearing unit that has been called the Wanship Formation of Eardley also is interpreted as having been derived from rocks uplifted by thrust faulting. The conglomerate at Wanship has been miscorrelated with conglomerate in the Coalville Member of Hale of the Frontier Formation at Coalville, Utah. Palynological studies reaffirm the Turonian age of the Coalville Member but show the conglomerate at Wanship to be Campanian-Maestrichtian in age, equivalent to the lower Evanston Formation of Wyoming, and probably related to movement of the Absaroka fault system. As a result of the determination of the age of the conglomerate at Wanship a hypothesized tectonic episode during the Turonian is shown to be unnecessary in the interpretation of geologic history of the Wanship area.

THRUST FAULTS AND STEEP FAULTS IN SOUTHWEST MONTANA AND EAST-CENTRAL IDAHO

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The Cordilleran fold and thrust belt in southwest Montana and central Idaho is now known to be more than 200 km wide, reaching from the cratonic crystalline rocks in Montana westward to the Idaho batholith. In the eastern part of this region, there are at least three major thrust plates: two relatively small lower plates that partly overlap and together define most of the leading edge of the thrust belt in southwest Montana; and the higher and much larger Medicine Lodge plate. These plates, and their associated systems of thrust faults, dominate the structure of the region as far west as the Lost River Range in Idaho. The thrust plates are characterized by pervasive overturned folds and imbricate thrust faults. Each thrust plate contains a distinctive sequence of rocks that differs from the sequences in the other plates and from the sequence on the craton to the east.

Conglomerates and other coarse clastic rocks of the Beaverhead Formation, eroded from the front of the advancing Medicine Lodge plate, were deposited in a peripheral moat or foredeep that formed in front of that plate. The small, lower plates incorporate much of this debris in imbricate thrust slices. A foreland bulge, complementary to the foredeep, is reflected in the broad uplifts that rose east of the thrust belt in Late Cretaceous time.

The trends of the uplifts in the foreland bulge seem to have been influenced by the structural grain in the older Precambrian crystalline rocks of the craton, which are cut by northwest- and east-west-trending faults of Precambrian ancestry and display strong northeast and north-south foliation. The Precambrian structural pattern is also reflected in the later, mid-Tertiary, drape-folded, basement cored block uplifts of southwest Montana; an example is in the Ruby Range, which is elongate parallel to the foliation in basement rocks, and is cut and partly bounded by faults of known Precambrian ancestry. The northwest and east-west trends are duplicated to a large extent in the linear mountain ranges of east-central Idaho. The linear ranges in Idaho most commonly have been described as tilted fault blocks or as basin-ranges bounded by normal faults, but they are better described as structurally flat-topped uplifts with monoclinally folded flanks. I suggest that they are drape-folded block uplifts above reverse fault-bounded crystalline blocks at depth, and that the faults defining the crystalline blocks have the same Precambrian trends and origin as those in the crystalline rocks exposed on the craton farther east. The normal faults so conspicuous along the mountain fronts in east-central Idaho appear to be relatively minor, secondary faults formed by gravitational sliding of slabs of rock from the shoulders of the uplifted mountain blocks; they suggest that the ranges have been extensively denuded by gravitational sliding and collapse.

Most of the steep normal and reverse faults of southwest Montana and east-central Idaho thus appear to have formed as a result of dominantly vertical movements of basement blocks first defined in Precambrian time. The division of the region into Laramide and Sevier tectonic provinces, as suggested by Beutner in 1977, is only partly appropriate. The Sevier province is clearly one of regional thrust faulting, but the apparent differences in mid-Tertiary high-angle faults do not reflect different tectonic controls, but rather the differing responses of thin and thick veneers of sedimentary rocks above differentially rising fault-bounded blocks of crystalline basement rock.

ALLOCHTHONS ALONG THE NORTHEAST MARGIN OF THE SNAKE RIVER PLAIN, IDAHO--REVISITED

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The concept of the presence of more than nine allochthons along the northeast margin of the Snake River Plain was presented for the first time in the 1977 Wyoming Geological Association guidebook (Skipp and Hait, 1977). The stratigraphy of each allochthon was described, and it was shown that the westernmost and structurally highest allochthons (Wood River and Milligen) last moved as discrete thrust sheets in pre-Late Cretaceous, probably Sevier, time, whereas the eastern Medicine Lodge and Tendoy allochthons may have moved as late as early Eocene time. All of the allochthons are cut by basin-and-range normal faults of relatively large displacement that were shown to flatten with depth. This complex geometry was diagrammed above a Lower Proterozoic basement dipping westward at about 15°. If an analogy is drawn with Canadian seismic work in the Foothills and Front Ranges near the international border (Gordy and others, 1977), the basement should dip westward at about 2° and generally should maintain this attitude across the area from east to west.

Depth to basement near the south end of the Tendoy allochthon is estimated to be at least 4,270 m (14,000 ft) below sea level on the basis of seismic and drill-hole data. Projected westward, the basement then would be more than 9,840 m (29,000 ft) below sea level in the vicinity of Fish Creek Reservoir. Lower Proterozoic crystalline basement is interpreted as being involved in low-angle thrusts in the Medicine Lodge and Tendoy allochthons.

In both of these allochthons, potential petroleum reservoir rocks of Mesozoic and late Paleozoic age locally have conodont color alteration index (CAI) values of 1-2, and are thus favorable for commercial oil production (Epstein and others, 1977). In the overlying Beaverhead allochthon, upper Paleozoic carbonates have CAI numbers of 4-5½, too high to be favorable for petroleum production even though the carbonates are underlain and overlain by potential source beds. Gas production remains a possibility, however.

Gravity work in the eastern plain (Mabey, 1978) indicates that the crust beneath the Cenozoic volcanic and sedimentary rocks probably is thinned, but not rifted. Therefore, the thrust system north of the plain probably is continuous with that south of the plain. Although the 80 or 90 km which separate the two areas present formidable problems with detailed correlation, recent study of the Mississippian and Pennsylvanian Systems on both sides of the plain (Skipp and others, in press) suggests that no relative strike-slip movement is needed along the axis of the plain before late Cenozoic time to account for distribution of facies and that the total amount of telescoping along thrusts is about the same on the two sides of the plain.

References cited

Epstein, A.G., Epstein, J.B., and Harris, L.D., 1977, Conodont color alteration--An index to organic metamorphism: U.S. Geological Survey Professional Paper 995, 27 p.

Gordy, P.L., Frey, F.R., and Norris, D.K., 1977, Geological guide for the Canadian Society of Petroleum Geologists 1977 Waterton-Glacier Park Field Conference: Calgary, Canadian Society of Petroleum Geologists, 93 p.

Mabey, D.R., 1978, Regional gravity and magnetic anomalies in the eastern Snake River Plain, Idaho: U.S. Geological Survey Journal of Research, v. 6, no. 5, p. 553-562.

Skipp, Betty, and Hiat, M.H., Jr., 1977, Allochthons along the northeast margin of the Snake River Plain, Idaho: Wyoming Geological Association Guidebook, Twenty-Ninth Annual Field Conference, p. 499-515.

Skipp, Betty, Sando, W.J., and Hall, W.E., in press, Mississippian and Pennsylvanian (Carboniferous) Systems in the United States--Idaho: U.S. Geological Survey Professional Paper 1110, Chapter AA.

PRELIMINARY INTERPRETATION OF RELATIONS AMONG MAJOR THRUST SYSTEMS IN SOUTHWESTERN MONTANA AND EAST-CENTRAL IDAHO

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Three major thrust systems are present in the Northern Rocky Mountains in southwestern Montana and east-central Idaho. From southwest to northeast these systems are (1) the Medicine Lodge thrust system, (2) the Sapphire and Ermont thrust systems, and (3) the Montana Disturbed Belt. We use the terms for these thrust systems in a general sense because we have ignored several associated smaller thrust systems. There are probably additional major plates west of the Medicine Lodge thrust system, and specific relations between the Ermont and Sapphire thrust systems are not known. The three major thrust systems described here are distinguished on the basis of stratigraphic and structural differences.

The Medicine Lodge thrust system is probably the oldest of the three systems. This thrust plate is composed of a distinctive stratigraphic assemblage consisting of Precambrian Y and Z rocks of the Lemhi Group, Swauger Formation, and Wilbert Formation and lower Paleozoic strata assigned to the Kinnikinic Quartzite, the Summerhouse Formation, and younger Paleozoic rocks. Structurally, the Medicine Lodge thrust system is characterized by (1) a prominent sole zone composed of mylonitic rocks, (2) flat thrust faults that form an imbricate lace-work pattern that isolates lenses of strata, (3) nearly isoclinal, overturned folds in Precambrian and Paleozoic rocks, and (4) coherent breccias formed along individual thrust faults. The Medicine Lodge thrust system extends northwest along the Idaho-Montana state boundary to the edge of the Idaho batholith. We suggest that the cataclastic zone present on the east side of the Idaho batholith could represent the draped and metamorphosed equivalent of the Medicine Lodge decollement.

The Sapphire and Ermont thrust systems form the middle tectonic unit; thrust faulting ceased on these systems prior to 80-77 m.y. ago. The Sapphire and Ermont thrust plates consist of Precambrian Y rocks of the Helena and Wallace formations and the Missoula Group of the Belt Supergroup. Lithofacies within the Missoula Group are coarser grained and more feldspathic on these plates than on the autochthon, and rock units are thicker on the Sapphire and Ermont plates. Lithofacies and nomenclature of lower Paleozoic and Colorado Group rocks are different on the Sapphire and Ermont plates than on other plates or the autochthon.

Structural features that distinguish these thrust systems are variable because sub-systems have individual structural characteristics. Most of the Sapphire thrust system is typified by these characteristics: (1) lack of a decollement zone exposed at the surface, (2) thrust faults that form an imbricate anastamosing pattern and that generally are steep at the surface and flatten at depth to the west and southwest, (3) folds that are broad and open in Precambrian and lower Paleozoic rocks and that are isoclinal and commonly overturned in upper Paleozoic and Mesozoic rocks, and (4) thrust fault zones that are characterized by incoherent breccia and gouge. The Ermont thrust system and the central part of the

Sapphire thrust system are typified by (1) flat thrust faults that form an anastamosing pattern, (2) tight folds that can be present in all sedimentary rocks, and (3) incoherent breccia and fault gouge that characterize thrust fault zones. The leading edge of the Sapphire thrust system trends east from Tarkio, Montana, near the Clark Fork River, to Elliston, Montana, where the leading edge of the thrust system turns south. The leading edge of this system is projected about 15 km east of Butte, Montana, and it probably is exposed in the Highland Mountains south of Butte. The Ermont thrust system trends south from the Highland Mountains to near Melrose and Dillon. Southwest of Dillon, it terminates in Horse Prairie. The north part of the Sapphire and Ermont thrust systems probably represents the north termination of part of the Utah-Wyoming Overthrust Belt.

The Montana Disturbed Belt is the easternmost of the major tectonic units and the youngest, with movement on thrust faults between 65 and 22 m.y. ago. The stratigraphic characteristics that distinguish this thrust plate are (1) cratonic eastern facies of the Belt Supergroup and lower Paleozoic strata, and (2) a thick seaway assemblage of upper Mesozoic strata that have few similarities to strata on the Sapphire thrust plate. Structurally, the Montana Disturbed Belt is characterized by (1) individual thrust faults that are traceable for long distances, (2) great variation in the types and distribution of folds, and (3) steeply dipping thrust faults in the east part of the system and flat thrusts in the west part (Mudge, 1972). The leading edge of the Montana Disturbed Belt traces the mountain front of the Northern Rocky Mountains from Glacier National Park to east of Helena, Montana. The south termination is not known, but thrust faults formerly assigned to the Montana Disturbed Belt in the Townsend Valley and the northern Tobacco Root Mountains belong instead to a minor thrust system, the Elkhorn thrust system, formed at the same time as the Sapphire and Ermont thrust systems.

References

Mudge, M.R., 1972, Structural geology of the Sun River Canyon and adjacent areas, northwestern Montana: U.S. Geological Survey Professional Paper 663-B, 52 p.

PROBLEMS FACING THRUST BELT EXPLORATIONISTS

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The explorationist deals with predictability. In the Idaho-Wyoming Thrust Belt, vertical and lateral structural predictability is hampered by detachment geometry, by post-thrust deformation, by lack of cylindricity of faults and folds, and by Cenozoic rock cover. By the same token, these problems can turn into additional exploration opportunities. Geophysical data are essential. Stratigraphic predictability is impaired by the complex structure. Interpretation of the Cretaceous system is complex because of detrital wedges shed from the western thrusts, internal deformation, and poor preservation.

Seismic data have been the key factor in all of the recent thrust belt discoveries. Many problems confront explorationists trying to acquire and interpret seismic data in this area. They range from weather and topography to static busts and velocity variation and occasionally no data. This part of the talk will attempt to present several of these problems and explain how they were resolved.